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THE CANADIAN FISH CULTURIST

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Editor's note: The first five articles in this issue were among the papers presented at a symposium on "Farm Fish Ponds as a Technique of Fishery Management", conducted in Ottawa on January 3, 1961, at the fourteenth meeting of the Canadian Committee on Freshwater Fisheries Research, under the sponsorship of the Fisheries Research Board of Canada.

The Canadian Fish Culturist is published under the authority of the Minister by the Department of Fisheries of Canada as a means of providing a forum for free expression of opinion on Canadian fish culture. In the areas of fact and opinion alike, the responsibility for statements made in articles or letters rests entirely with the writers. Publication of any particular material does not necessarily imply that the Department shares the views expressed. In issuing The Canadian Fish Culturist the Department of Fisheries is acting only as an instrument for assisting in the circulation of information and opinion among people in the fish culture field. Those who may wish to discuss articles which have been published in The Canadian Fish Culturist are encouraged to do so and space will be made available.

Correspondence should be addressed to the DIRECTOR, INFORMATION AND CONSUMER SERVICE, DEPARTMENT OF FISHERIES, OTTAWA, CANADA.

Published under Authority
of
HON. J. ANGUS MACLEAN, M.P.,
Minister of Fisheries

Fish Ponds in Canada - - A Preliminary Account

by

M. W. Smith

Fisheries Research Board of Canada, Biological Station, St. Andrews, N.B.

Technological advances provide Canadians with more leisure for recreation. Fishing ranks high, if not highest, as a participant sport. Canada has an abundance of streams and lakes in which good angling is yet to be had. However, angling effort by residents and tourists increases in Canadian fresh waters. The yield of sport fish to the individual angler, and possibly the total yield as well, has declined in our more accessible and heavily fished waters. There results a demand for more sport fish.

Increased production of sport fish can only come from altering natural environments in a positive fashion for the well-being of more fish, or by correcting harmful action by man on fish life in his use of water and watersheds. Pond formation and management is a procedure for greater production of sport fish. By pond formation new aquatic environments are created, with more control of both water and fish than is possible under natural conditions.

Reference to fish ponds in United States

A discussion of the status of fish ponds in Canada can scarcely be given without at least passing reference to the large development of such ponds in the United States. It is now estimated that there are about two million farm ponds throughout that country. The majority of these are managed in varying degree to produce fish. Dictated by climate, warm-water fish rather than cool-water species are principally involved. However, trout are successfully reared in farm ponds in the northern states. Also in these areas, the commercial production of trout for sale as food, or for disposal to anglers on a catch-and-pay basis, has assumed large proportions. Much has been invested by private citizens in the business. An example indicative of these developments is the U.S. Trout Farmers' Association, formed in 1953, with its trade journal, the *U.S. Trout News*. However, it is not implied by these remarks specific to the United States that we should ignore the long history of fish ponds in many countries of the world, and the advances there made in research and management.

Doubtless much of the interest in fish ponds in Canada, and opinion, cautious to enthusiastic, with respect to their value and future status, stem from what has been done in the United States. Certainly, with proper equation to Canadian needs and conditions, there is no question that we can learn a great deal and profit from American experiences, both favourable and adverse.

Status of Fish Ponds in Canada

The writer has first-hand information on fish ponds in only a limited area. Information and opinion were sought from freshwater fishery investigators and administrators across Canada (see acknowledgments). Contact was also made with a number of Americans in these fields. Our effort to date can provide only a preliminary picture of the fish pond situation in Canada.

General Comments

Need for fish ponds. A fact which we must initially bear in mind is that streams and lakes in large sections of Canada still provide good angling for sport fish. For quite some time to come we can expect nature to produce most of our sport fish with little or no management on our part. The demand and need for more sport fish may best be considered against this background. One rather obvious conclusion is that most pressing demand and need will and does come from our populated areas, where production under natural conditions cannot cope with angling pressure and spoilage of waters for fish life by man's activities. There appears to be general agreement that in these situations, and they increase area-wise, fish ponds, among other fish-cultural measures, can do much to meet the need for more sport fish. There is recognition of the fact that for increased production of sport fish in the future there is the need for more control of fish and water.

Water areas created by pond formation. In our more general thinking of fish ponds, they tend to suffer from what may be termed "a small-water complex". Artificial fish ponds generally are of small acreage. In aggregate, even if the number were large, their area would remain small in comparison to that of natural waters in Canada. However, fish ponds can provide a substantial area of fishing water. In those situations noted above where need appears greatest, fish ponds may become the major or the only water areas that are suitable for sport-fish production and also readily accessible to the angler.

Number of Fish Ponds

Only a crude estimate of the number of fish ponds in Canada is possible from the information at hand. We give an estimate of 10,000 ponds. However, a very considerable error may be attached to this estimate since it would appear that for some areas a census of fish ponds has not been made.

Well over one-half of the ponds are in southern Ontario and southern Quebec, i.e. they are located in major urban and agricultural areas. They are areas where natural sport-fish environments have been seriously disturbed. A large number are farm ponds in the multiple use of which, however, the production of sport fish is a major interest.

Thousands of farm ponds have been created on the prairies. The federal Government under the Prairie Farms Assistance Act assisted in their construction in recognition of needs to conserve water supplies. It has been found, however, that a large proportion of these ponds are unsuitable for fish production. Some are operated as trout ponds, but it is considered that warmer-water species, such as perch and centrarchids, are more adaptable.

Over much of the remaining area of Canada streams and lakes provide good fishing. Fish ponds have been developed in localized areas, again for the most part in relation to urban and agricultural developments. With the interest growing, there have recently

been established a number of commercial and private fish farms in British Columbia. The number of fish ponds in the Atlantic Maritime Provinces is small. Most interest and development has been shown in Prince Edward Island and the Madawaska region of New Brunswick. There are about 200 trout ponds in the former area and a count of 28 in the latter. A few fish ponds are scattered over the rest of New Brunswick, in Nova Scotia, and on the Avalon peninsula of Newfoundland.

Interest and Attitudes

The construction of fish ponds in appreciable numbers is a relatively recent development in Canada. Interest increases and becomes more widespread, as evidenced by the building of new ponds each year. A summary report (1959) on fish ponds in the Erie district of Ontario, for example, shows the expansion (without a statement of numbers involved) in that area: 37 per cent of the ponds have been in existence for more than 10 years; seven per cent were constructed five to 10 years ago; and 54 per cent were built within the last five years.

The initiative in fish-pond construction has been largely with private individuals. In general, interest on the part of government fisheries departments has followed to provide regulation and to meet requests for information and advice on pond fish management. Fisheries departments have understandably been primarily concerned with regulation and attempts to maintain the supply of sport fish in streams and lakes. With respect to fish ponds their attitudes are largely based on judgment whether there is need for more sport fish locally and whether fish ponds have value to meet this need in part. There has resulted, as was to be expected, differences in the amount of support that Canadian governments have given to the development of fish ponds, either private or public.

In British Columbia the stand appears to be taken that public funds should be spent only in support of the public sport fishing, with no aid to commercial or private game fish farms or ponds. As noted, the construction of farm ponds on the prairies has been materially assisted by the federal Department of Agrculture. Scientific investigation to determine the suitability of these ponds for fish has been supported by grants from the National Research Council and the Saskatchewan Department of Natural Resources. The Alberta Department of Lands and Forests has a program of investigating, stocking and managing suitable farm ponds for the production of trout, so long as public fishing is permitted by the landowner. The Alberta Government has under consideration the setting up of regulations to permit private sport fish enterprises. There are no such enterprises in Manitoba, but the provincial Department of Mines and Natural Resources, through its Fisheries Branch, has interest in fostering their development.

In Ontario, the Departments of Agriculture, Planning and Development, Lands and Forests, and various Conservation Authorities actively support by advice and investigation the establishment of private fish ponds, particularly on farms in the southwestern part of the province. The Ontario Agricultural College now offers training in fisheries management and is active in fish pond research.

The establishment of private fish ponds in Quebec is encouraged by the provincial fisheries department. Direct aid is not given in the construction of fish ponds, but technical advice is made available. At Lyster Lake there has been established, as a cooperative effort between government and fishing clubs, a number of "model" ponds.

These illustrate to the increasing number of interested individuals the most suitable construction techniques for ponds in that area, and demonstrate methods for effective use of natural water supplies.

With many streams and lakes in their forested areas, the provincial governments of New Brunswick, Nova Scotia and Newfoundland have given minor consideration to artificial fish ponds. Prince Edward Island is much interested in developing its excellent brook trout waters as tourist attractions. The Department of Industry and Natural Resources has an active program of forming trout ponds for public fishing.

The federal Department of Fisheries through the Fisheries Research Board has underway a research program on trout ponds, with the investigation principally centered on Prince Edward Island. The Fish Culture Development Branch has had concern, but a minor one, with private and public fish ponds. It is the policy of the federal Department of Northern Affairs and National Resources to alter the natural conditions in national parks as little as possible in providing facilities for the public. Artificial fish ponds are as yet not considered desirable.

Species of Fish

Trout are favoured species in Canadian fish ponds. Cool waters over much of our area present suitable habitats for salmonids. Both brook and rainbow trout are quite amenable to pond culture, and they receive prime attention. Brown trout are infrequently considered.

Summer water temperatures in ponds of some regions of Canada become too warm for trout. Warm-water species are necessarily involved. The extent to which the bass-bluegill, or the bass-shiner combinations, so successful in American fish ponds, can be adapted to the Canadian climate remains largely to be explored.

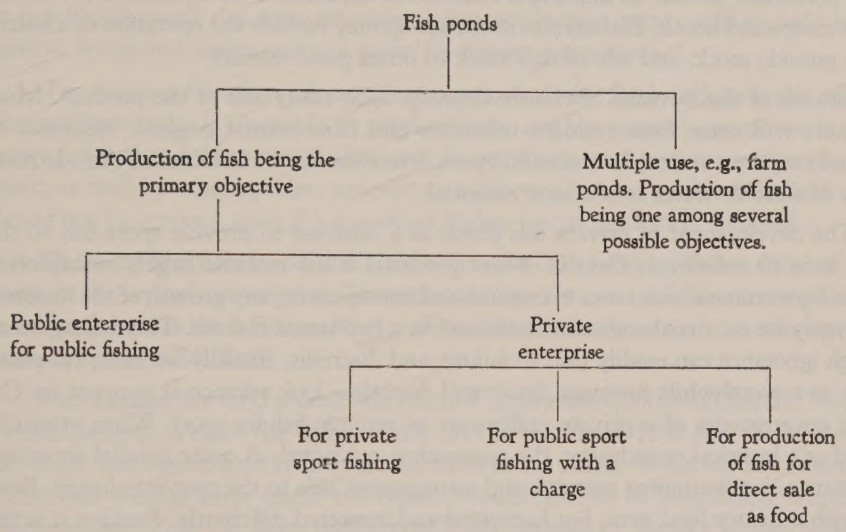
Anadromous salmon and trout waters will often be harmed by future industrial developments, and the rearing of these species to the sea-going stage may well assume increasing importance. For this, fish ponds, as distinct from the more conventional holding facilities at rearing establishments, may play a useful role.

Information for Application

Fisheries research has not yet provided formulae for assured success in forming sport-fish ponds under the variety of conditions of the Canadian climate and terrain. Our knowledge is certainly not definitive, but much is known. A pressing need, but no mean task, is the consolidation of what is known into a form suitable to guide practical application in the various areas. Mechanical techniques and physical construction requirements in a variety of situations have been described and are workable. The life histories and environmental requirements of brook and rainbow trout, and black bass, the game species most adaptable and desired in pond culture, are reasonably well known. Artificial propagation of these species has as long a history in practice as any fish cultural measure. Regionally at least, there is knowledge of the qualities of waters to indicate where fish-pond formation is most feasible. We can draw on the experiences of workers in other countries. Actually private enterprise in several locales has shown that practice is possible with a reasonable probability of success. Accepting the worth of fish ponds to produce sport fish, there is need on a regional basis for research and management to demonstrate the best application possible with available information, and in so doing to obtain additional knowledge for refinement of the procedure.

Classification of Fish Ponds

A number of classifications of fish ponds on various bases is obviously possible. We present a simple one based largely on their use in the production of sport species. It will be apparent that there is much overlap among the several categories.


Fish ponds
Production of fish being the primary objective
Multiple use, e.g., farm ponds. Production of fish being one among several possible objectives.
Public enterprise for public fishing
Private enterprise
For private sport fishing
For public sport fishing with a charge
For production of fish for direct sale as food

Public Enterprise for Public Fishing

Sport-fish research and management programs that are in progress in Canada deal largely, as is readily understandable, with maintenance and improvement of fishing in the many existing natural waters. Artificial fish ponds are unique in that new water areas are created. These are water areas, as previously remarked, in which more control of water and fish is possible than in natural environments. Pond formation is a step toward domestication of the fish, that is toward aquiculture. It would appear a logical and effective procedure to produce more fish where the natural supply is low or becomes depleted. However, natural waters exist, while obviously fish ponds require money and effort to create. This aspect of fish ponds, and obtaining suitable property rights for construction, are among the deterrents in their development by governments for public fishing, even if their worth is accepted.

Public fish ponds can serve as tourist attractions. The province of Prince Edward Island has constructed a number of such ponds on streams in recent years. It is reported from rather casual assessment that the ponds function well in this role.

Private Ponds for Private Fishing

Private fishing ponds with angling restricted to the owner and friends have much appeal. They are looked upon with definite favour by some government fisheries departments, although they may require regulation and lead to requests for information in building them and in subsequent management. They are looked upon as contributing to the supply pool of sport fish, and, if numerous, as materially reducing fishing pressure on neighbouring natural waters.

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Private Enterprise for Public Fishing

This sort of enterprise is viewed as a business. It may be full-time or subsidiary to another occupation. The business essentially operates by selling sport fish reared in privately-controlled ponds to anglers for a fee, such as so much per fish or per pound. These ponds can assume an important function as adjuncts to the operation of summer tourist camps and hotels. Elaboration in the set-up may include the operation of a hatchery to provide stock, and sale of this stock to other pond owners.

Success of the business obviously depends upon ready sale of the product. Most customers will come from resident urbanites and from tourist anglers. Nearness to population centres and ready accessibility are dominant factors in location. An adequate supply of suitable water is of course essential.

The development of private fish ponds as a business to provide sport fish to the angler is in its infancy in Canada. What potential it has remains largely unexplored. Without government assistance in research and management, any growth of the business will largely be on a trial-and-error basis, and in a haphazard fashion. This management through ignorance can readily lead to failure, and discredit, initially at least, its possibilities as a worthwhile business. Some will doubtless look askance at support by Canadian governments of a private endeavour to provide fish for sport. When primarily viewed as a business or industry, the approach is not novel. A quite parallel situation, for instance, is government research and management aids to the oyster industry. Both deal with a luxury food item, but harvested and marketed differently. Perhaps it is the adjective "sport", held in antithesis to "commercial", that tends to cloud thinking in the development of trout fisheries by private enterprise for profit, and deters government support in such development. In fact, however, the present-day prosecution of our sport fisheries obviously has many commercial facets. It is unfortunate that the monetary worth of our sport fisheries lacks focus in public attention in much of Canada for want of economic evaluation.

Private Enterprise for Producing Fish for Direct Sale as Food

Most of what has been said about private enterprise for production of trout for public angling is applicable in this situation. Additional facilities to handle and market the fish as food are required. The product is disposed of through commercial food channels and is subject to the problems and vagaries of food marketing.

Trout are carnivores. They stand at a high level in the food chain. Thus trout must be viewed as a "luxury" food item demanding a commensurately high price if they are to be grown with profit. A joint committee of the American Fisheries Society and the U.S. Trout Farmers' Association reported in 1959 that the cost of producing trout (a large amount being rainbow) of all sizes by federal and state agencies in the United States ranged from 20¢ to $1.80 per pound, with an average cost of 89¢. In 1960, dressed rainbow trout raised by American trout farmers retailed from 85¢ to $1.00 a pound on American markets.

There is at present a minor production of trout in Canada for the food market. The Dominion Bureau of Statistics reports that frozen trout to the value of $365,000 were imported into Canada in 1959 from Denmark and Japan. The value of such imports in 1956 was about $44,000. These data suggest a growing market for such fish in Canada,

but to what degree is not clear. There is apparently the practice of repacking imported trout in Canada with subsequent export to United States. With lower cost of production, some government subsidy, and marketing through centralized co-operatives, producers in Denmark and Japan are able to export frozen trout to the United States and present strong competition to the domestic producers. The Canadian grower would be faced with much the same situation unless production costs could be held to competitive levels and assistance was given by import restrictions.

The species of trout produced almost exclusively for food markets is the rainbow. The rainbow trout is amenable to pond culture, and the general experience is that it grows faster than other species. However, many, if not most people consider the brook trout, as well as other species, superior to rainbow trout as a table fish. Such appeal should not be ignored, even if a somewhat higher-priced product is involved.

There are likely areas in Canada for commercial fish farming. Prince Edward Island is one in the writer's experience. There the quality of water is highly suitable for brook trout, and there is the additional factor of readily obtaining waste from commercial sea fisheries as a possible food.

Fish farming for food production remains largely unexplored in Canada. However, for fish farming to make the best contribution to the future food pool of this country, fish other than trout (carnivores) would have to be raised. What we at present term coarse fish, such as carp, tench and others, would have to be considered, without expectation, however, of those production levels realized in warm climates where fish farms make major contributions to the food supply.

Farm Fish Ponds

The farm pond provides water for multiple use. The production of fish is, however, a major concern. Both agricultural and fisheries interests are usually involved. For the most part the very large expansion of farm fish programs in the United States resulted from co-operative effort by the Soil Conservation Service, the Fish and Wildlife Service and state conservation organizations. Thus in New York State, where there are about 15,000 farm ponds, increasing roughly at a rate of 1000 per year, there has been an intensive research program to formulate fish management in these ponds by the Cornell University Conservation Department, on contract from the New York State Conservation Department, with financial assistance from the U.S. Fish and Wildlife Service. From this co-operative effort has stemmed the successful farm pond management practices for trout production which are recommended by the U.S. Soil Conservation Service and Fish and Wildlife Service throughout the northeastern United States. Reference has been made to the American experiences since they clearly illustrate the value of a co-ordinated approach by interested agencies to result in a worthwhile development of farm fish ponds.

Farm fish ponds are usually held for private fishing. The extent to which they are opened to public angling, with or without fee, is the farmer's decision. Multiple use is a primary objective in their formation, but they contribute to the supply of sport fish. In this light the increasing attention and support that farm fish ponds are receiving from fisheries agencies are quite justified in their most useful development.

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Summary

1. The demand and need for more sport fish appear most acute near urban centres and in agricultural areas. There the productive capacity of readily accessible, and often harmfully altered, natural waters is insufficient to cope with the angling pressure.

2. Formation of fish ponds is one among other fish cultural procedures designed to provide more sport fish. It is unique in that it creates new water areas in which both water and fish are subject to more control than possible under natural conditions. It is the first step in domestication.

3. A rough estimate of the number of fish ponds in Canada is 10,000. The majority are in Ontario and Quebec. Most initiative in their construction has been shown by private individuals, rather than government. Interest has been much stimulated by the large development of fish ponds in the United States.

4. The sport species of most interest and most amenable to pond culture are rainbow and brook trout. Centrarchids are of interest in warmer ponds.

5. As a whole Canadian governments view fish ponds to provide sport fish with favour. However, they show various attitudes with respect to regulation and actual support in their development, either as public or private ventures.

6. Much information exists on the construction and management of fish ponds. However, further review and consolidation of this information into useful form for immediate practice under Canadian conditions, as well as continued research and practical demonstration for more definitive management, are needed for development of fish ponds on more than a trial-and-error basis.

7. Fish ponds can be developed under public auspices for public fishing, or by private enterprise for private fishing only, for public fishing for a fee—a business, and for the production of sport fish as a "luxury" food item—also a business. Of much importance are farm ponds for multiple use of water, of which a common one is the production of sport fish.

8. The opinion is advanced that best development of fish ponds to provide public sport fishing will come from private enterprise as a business, selling the product for a price. Government support of such enterprises as businesses, by research and practical demonstration of regional management needs, is not a departure from what is now done in Canadian fisheries.

9. Farming trout for sale as a "luxury" food item requires demonstration of its possible worth in suitable Canadian waters. It is not conceived that farming trout—a carnivore—would make the best contribution to the Canadian food pool. For future possibilities in this direction what we now consider coarse species, but utilizing more of the productive capacities of waters, would have to be considered.

10. For best development of the farm fish pond, with its multiple use of water, coordinated assistance to the farmer by government agricultural and fisheries agencies is needed.

Acknowledgments

In the preparation of this account, information and comment on fish ponds were sought from the following persons. Their attention to the request is gratefully acknowledged. Possible misinterpretation of facts and opinions may have been made by the writer. For any of such he assumes responsibility.

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Vital Statistics of Trout Populations in New York Farm Ponds

by

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The data reported here are principally those obtained from 167 pond inventories conducted in the period 1952-58. Findings of Saila (1949-51) have been included in determining over-all rates of natural mortality.

Because of unsuitable environmental conditions, trout seldom reproduced successfully in New York farm ponds, although they frequently spawned.

There were no differences in natural mortality rate (n) or longevity between brook, rainbow, or brook x brown hybrid trout of comparable ages, nor was mortality related to stocking rate (up to 800 fingerlings per acre). Natural mortality varied markedly with calendar year, season, age of fish, and pond water supply (spring vs. runoff water). Duration of bottom water temperatures above 73° F. was the factor which most influenced the natural mortality of farm pond trout in central New York. Class mean natural mortality rates of various age groups of farm pond trout were as follows:

	Half years					Whole years				
From age.....	O	O+	I	I+	II	O	O+	I	I+	II+
To age.....	O+	I	I+	II	II+	I	I+	II	II+	III+
Nat. mort. rate (n)..	.70	.30	.45	.45	.55	.80	.60	.75	.80	.80

Natural mortality of spring fingerlings during the first season following stocking in farm ponds was extremely variable and fall fingerlings gave much more dependable results, particularly in ponds where holdover fish from an earlier plant were present.

Growth of farm pond trout did not differ with species, nor with the water supply, size, or age of ponds within the ranges of available data. Length and weight increments varied with age of trout, and were somewhat slower between late October and mid-April than in the summer period. In trout up to age I+, average growth rate decreased only slightly with increasing mean population densities above 400 trout per acre. In the I+ to II+ age interval, there was some evidence of a negative relationship between growth rates and mean population densities above 100 fish per acre. Mean biomass (pounds per acre) increased steadily with mean population density up to the maxima of 700 yearling and 400 2-year-old trout per acre tested.

Using class means of increments in average length and weight from individual ponds, the sizes of farm pond trout at various ages following stocking as 5.6-inch fall fingerlings are as follows:

Age	I	I+	II	II+	III	III+
Total length, ins.	8.1	10.1	11.1	12.8	—	14.2
Weight, lbs.	0.23	0.50	0.64	0.89	—	1.35

Mean growth and natural mortality rates for half-year intervals have been utilized to determine expected standing crop in each half year of pond life. Standing crop reaches a maximum when the trout are age I+. In ponds stocked with 600 fall fingerlings per acre, this maximum averages 110 pounds per acre, but varies widely with the large variations in natural mortality rates among individual ponds. In the course of the investigation, ponds were encountered which contained standing crops as high as 240 pounds of trout per acre (age I+). The data indicate conclusively that New York farm ponds must be restocked with trout every other year to provide adequate fishing.

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A Review of Farm Trout Ponds in Southern Ontario

by

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Introduction

The history of farm fish ponds in Ontario would in itself present an interesting story which will be remarked on only briefly. As elsewhere, the first ponds were constructed for water power, and by the middle of the 19th Century dams had been built on practically all of the watersheds flowing into the lower Great Lakes. Many of these early ponds soon became community recreational centres for skating, swimming, fishing, and other social activities and were, in effect, multipurpose ponds.

Before the turn of the century, mill ponds were being acquired or new ponds built specifically for private speckled trout fishing, and several of the old fishing clubs still in operation date back to that time. Information on the early trout pond fisheries is difficult to acquire although the continuous records of one private trout club date back to its formation in 1895.

The first government interest in Ontario ponds resulted from public concern over the construction of dams on tributary streams of Lake Ontario which threatened the spawning runs of salmon then abundant in the lake. Legislation as early as 1840 gave consideration to this matter. Following the establishment of the Newcastle Fish Hatchery in 1866 and its subsequent operation by the federal Government, speckled trout became available for stocking both public and private waters and apparently many ponds were stocked with fish from this source. As early as 1895, speckled trout could be purchased from a private hatchery located near Toronto.

Present government interest in Ontario farm ponds is shared by several provincial agencies: The Department of Lands and Forests, through its Fish and Wildlife Branch, provides a limited extension service on the development and management of farm fish ponds. It is also subject to considerable pressures to provide hatchery-reared sport fish for private ponds. This it may do providing that there are surplus stocks and fish are not available from private hatcheries. The approval for dams to be constructed on streams is the responsibility of the Surveyor-General.

The Department of Agriculture, through its Agricultural Representatives and engineering staff, carries on an extensive farm pond extension program concerned primarily with the construction of ponds for agricultural or multipurpose use. The suitability of these ponds for fish, until recently, has been only a minor consideration although a number are used for trout or warmwater fish production.

The Department of Planning and Development and particularly its progeny, the river valley authorities, have an extension interest in the recreational aspects of pond

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development. The Metropolitan Toronto Conservation Authority (representing the amalgamation of several river valley authorities) has established public fishing ponds in one of its "Conservation Areas".

Fundamental fisheries and limnological research on farm ponds is an interest of the fisheries section of the Department of Zoology at the Ontario Agricultural College. This program functions with a measure of co-operation with the aforementioned agencies and has received substantial financial support from conservation funds of the Canadian National Sportsmen's Show.

Present Status

Geographically, farm ponds are limited largely to southern Ontario to the south of the Pre-Cambrian Shield. A survey conducted in 1959 revealed that there were no less than 10,500 usable farm ponds in this area. Probably there are considerably more of which there is no record.

Although interest in farm ponds dates back over many years, their popularity increased notably about 1950 and has remained since at a relatively high level. Government agencies concerned with farm ponds reported a total of nearly 1100 enquiries on pond development and management in 1959. These ponds are built for a variety of purposes. About 50 per cent of the ponds built between 1950 and 1959 were primarily for fire protection and watering stock, about 10 per cent for irrigation, and about 10 per cent for fishing. The remaining 30 per cent were of a multipurpose type with fishing an important consideration. Also, a number of fire protection and irrigation ponds provide fishing as a by-product.

The purpose for constructing farm ponds varies significantly from area to area. For example, in Norfolk County along the shore of Lake Erie about 95 per cent of the 1356 ponds (in 1957) are of the dug-out type dependent on ground water and built for tobacco irrigation. However, many of these are satisfactory for either warm-water or cold-water fish and rainbow trout are stocked often on a "put-take" basis.

By contrast, in Dufferin County, with marginal agricultural land and abundance of spring water, the emphasis is almost entirely on recreational trout fishing waters. The majority of these ponds are used for private angling, although a number of owners derive a revenue from the lease of fishing rights on a daily or seasonal basis. Several private fish hatcheries are located in the area.

Near centres of population, the real estate value of rural lands are increased significantly by the presence of fish ponds. These properties are in continuous demand by city people seeking recreational facilities near home.

Trout Production

Most southern Ontario farm ponds, if sufficiently deep, will support some species of fish. These ponds may be conveniently separated into warm-water and cold-water types with a division based on a maximum summer water temperature above or below 72° F. at a depth of three feet from the surface. Coldwater ponds are generally preferred in Ontario on account of their ability to support members of the Salmonidae. The preferred fishes are the speckled trout, *Salvelinus fontinalis*, and the rainbow (or Kamloops) trout, *Salmo gairdneri*. The remainder of this paper is devoted to some rather general

observations on the use of cold-water ponds for trout production and angling in southern Ontario drawn from the findings of the Ontario Agricultural College pond research program.

Trout production in farm ponds is obviously dependent on either natural reproduction, stocking with hatchery-reared fish, or a combination of both. A great many southern Ontario farm ponds have been constructed on headwater streams which provide a suitable stream-pond combination for natural reproduction. Occasionally, there is some natural reproduction in the ponds themselves. Many ponds continue to provide recreational angling year after year with naturally-produced fish. At the other extreme, there are those ponds without facilities for natural reproduction in which fishing is maintained solely by stocking programs. Included in this latter type are dug-out ponds, most spring-fed ponds, and the majority of ponds built on non-headwater streams.

Harvest levels are dependent not only on the standing population of the preferred size of trout, but also on certain human factors. Firstly, Ontario ponds are often under-fished for maximum production with the result that, provided that supplies of fish are available for angling, harvest levels may be closely related to fishing pressure. Comparatively few fish ponds have angling pressure in excess of 100 man-hours per acre per year although a fishing effort approaching this level, or higher, is necessary to exploit fully many standing populations of trout.

Secondly, angling success per unit effort does not present an unbiased picture of the availability of trout, as success is dependent on the type of bait (in many ponds only fly-fishing is permitted) and on the proficiency of the individual angler. Angling success differs remarkably even among members of the same fishing club.

Thirdly, the selectivity of anglers in keeping trout only of a preferred size, while returning smaller trout to the water, may result in a considerable numerical difference between total catch and actual harvest. Examples of this are presented in Tables 1 and 2, listing ponds where from 36.5 to 71.4 per cent of the total catch was not actually harvested, but returned to the water. Catch and harvest statistics should not be confused when describing or comparing trout production and, in fact, both may be necessary to gain an insight into a standing trout population, or to appraise the quality of angling.

The maximum production of trout which may be expected from ponds dependent solely on natural reproduction is difficult to ascertain, harvest being dependent on both biological and human factors. The highest continuous harvest level on record for Ontario ponds comes from one of three ponds in a 5.1 acre fishing unit from which an average of 71.4 pounds of trout per acre were harvested annually over the 1956-1959 period. Fishing records for the pond unit over the four-year period is given in Table 1, during which time 3007 man-hours of angling caught 12,802 trout, or 4.3 fish per man-hour. Only 4709 fish, or 1.6 trout per man-hour, were actually harvested (kept).

In ponds lacking natural reproduction of trout, the extent and size composition of the standing trout population is established artificially by the fish stocking programme. Thus the harvest level is determined, firstly, by the stock of fish made available for angling and, secondly, by the fishing pressure exerted on the stock. The management of ponds on a "put-take" basis is readily adapted to meet most angling requirements and there is a variety of stocking programs in use by Ontario pond owners. Three examples of different uses of "put-take" management will be cited.

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TABLE 1.

Fishing statistics of a private trout club, 1956-1959. Speckled Trout Production is dependent solely on natural reproduction.

Pond	Surface Area (acres)	Man-hours of angling	Catch Statistics			Rejection Rate (% of catch)	Total Annual Harvest	
			Caught	Returned	Kept		per acre	per man-hour
1.....	1.6	976	4,282	3,056	1,226	71.4	191	1.8
2.....	1.6	846	3,427	2,071	1,356	60.4	212	1.6
3.....	1.9	1,185	5,093	2,966	2,127	58.2	280	1.2
Total ...	5.1	3,007	12,802	8,093	4,709	63.2	231	1.6

In the first case, modest angling requirements are supplied by plantings of 200 yearling speckled trout (5-7 inches in length) in June of alternate years. The planted trout are recovered mostly during the first and second years of fishing although a few fish usually escape until the third year. Since construction of the pond in 1952, some 60-90 per cent of each planting has been recovered by about 100 man-hours of fishing. The growth rate of the trout, feeding on natural foods only, is above-average even for fertile ponds. The fish reach an average total length of 10.5 inches and a weight of nearly eight ounces by September of the first year, 13-15 inches and 17 ounces by September of the second year. Those fish surviving until the third year have measured up to 16 inches with weights to 26 ounces. Angling success from the most recent planting (1958) was 0.8 trout, or 0.5 pounds per man-hour.

In the second case, angling requirements necessitate a high production of speckled and rainbow (Kamloops) trout from a one-acre pond. Management procedures include aquatic weed control by fertilization and a stocking policy based on an analysis of harvest records. In some years stocking is unnecessary. In most years, plantings not exceeding 500-1000 autumn fingerling or spring yearling trout of either species are made. The growth rate has been slightly lower than that of the speckled trout in the case cited above. Rainbow and speckled trout have been considered together as both species do equally well in the pond, and the approximate ratio of the two species in the harvest is predetermined by the stocking ratio. Fishing statistics are presented in Table 2 for the 1957-1960 period when 618 man-hours of angling captured 3318 trout, of which 1507 were harvested. Annual harvests averaged 377 fish or 210 pounds per acre. Angling success was 2.4 fish or 1.4 pounds per man-hour. The harvest levels of 1957 (736 fish per acre) and 1960 (377 fish per acre) are very much above average for Ontario ponds.

The third case is the most extreme use of "put-take" management and one employed by Ontario's largest private fishing club. Trout are propagated in their own hatchery and grown to a length of 10-12 inches or more in rearing ponds where they are fed artificially. The large trout are released into the fishing ponds periodically during the angling season to replace those harvested by anglers. This type of fishery does not enter into the normal concept of farm fish ponds but can, of course, result in a tremendous harvest of trout limited only by the hatchery production and the ability of anglers to recover the stocked fish.

TABLE 2.

Fishing statistics of a private pond, 1958-1960. Fish production (speckled and rainbow trout) is dependent solely on hatchery-reared trout.

Year	Man-hours of angling	Catch Statistics			Rejection Rate (% of catch)	Total Annual Harvest	
		Caught	Returned	Kept		per acre	per man-hour
1957.....	236	1,901	1,165	736	61.3	736	3.1
1958.....	73	333	192	141	57.8	141	1.9
1959.....	125	357	189	168	52.9	168	1.3
1960.....	184	727	265	462	36.5	462	2.5
Total.....	618	3,318	1,811	1,507	54.6	377	2.4

Intermediate between those ponds with adequate natural reproduction and those dependent on hatchery-reared fish for their trout populations there are a great number of ponds which are restocked periodically, although trout are known to reproduce naturally. Evidence is available for several ponds to show that natural reproduction can be assumed erroneously to be significant although, in fact, adequate to meet angling requirements. An example of this situation is afforded by a private fishing club which stocked its ponds with hatchery-reared trout almost annually for over 50 years. Stocking was discontinued several years ago but there has been no decline in the numbers of trout harvested.

On the other hand, many pond owners are convinced of the value of planting hatchery-reared trout to supplement natural stocks although data is generally lacking on the actual contribution which they make to either standing trout populations or the quality of angling. A detailed study of each pond and its fishery is necessary to provide this information because the extent of the contribution is, of course, dependent upon a number of variable factors. Hatchery-reared trout may contribute directly to the harvest through their subsequent recovery by angling, or to trout production by becoming forage for larger trout. Plantings of trout fry are often made on this latter assumption with seemingly satisfactory results. Further research is necessary before an evaluation can be made of the relative contribution which plantings of hatchery-reared fry, fingerling, yearling, or two-year-old trout make to ponds with naturally-reproducing trout populations.

In this paper, several examples of high harvest levels from Ontario fish ponds have been given. Limnological studies on these and other highly productive ponds have indicated certain similarities which will not be considered in this paper. However, the following general conditions which are common among productive ponds may be of interest to the reader:

Firstly, a surface area of $\frac{1}{4}$ to two acres. Smaller ponds are of little value for fish production. Larger ponds often present serious complications from the standpoint of aquatic weeds and coarse fish control. However, several ponds of five acres provide excellent fishing.

Secondly, a maximum depth not less than six feet if there is a flow of water through the pond. Otherwise, a depth of 15 feet or more may be required to prevent winter kill. However, the possibility of an occasional winter kill should not deter the use of a pond for trout production. Often above-average production comes from borderline ponds.

Thirdly, an outflow from the pond not exceeding two c.f.s. per surface acre of pond. Lower outflow rates are usually desirable and rainbow trout, in particular, do well in dug-out irrigation ponds with no outflowing water. The flushing effect of outflows above two c.f.s. may present difficult management problems.

Fourthly, a summer water temperature reaching 65-70° F. at a depth of three feet from the surface. Surface temperatures may reach 75-80° F. Within this temperature range the optimum growth of both speckled and rainbow trout is realized. At lower temperatures, the growth rate declines significantly and in many spring-fed and headwater ponds, the largest trout may not exceed 8-10 inches in total length in contrast with trout of 14-15 inches in the warmer ponds.

Fifthly, an angling pressure of at least 50-100 man-hours per year. Trout harvests from the majority of private ponds can be raised substantially by an increase in fishing activity. In view of the short life expectancy of trout in Ontario farm ponds, both native and stocked trout should normally be fished intensely when they reach a size acceptable to anglers if maximum use is to be made of the trout production.

The Genetics of Selection in a Fish Population

by

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When fishery biologists think of genetics, they are usually thinking in terms of ordinary Mendelism, that is, problems where fish of two different types are crossed, and then the F_1's either mated together or else backcrossed to one of the original parents. This type of genetics could be illustrated by the following cross:

P_1	Silver coloured fish BB		×		Black fish bb	
F_1			Silver Bb			
F_2	1 Silver BB	:	2 Silver Bb	:	1 Black bb	

This type of genetics is not applicable when we are dealing with selection problems, or any type of problem which deals with populations rather than individuals, and with quantitative characters rather than simple Mendelian ones. In order to deal with the genetics of populations we have to shift to a nomenclature which takes into account the frequency of each gene in the population, and the behaviour of these frequencies under different systems of mating and selection. Such a system applied to the example above would be, let r equal the frequency of the recessive gene, and d equal the frequency of the dominant gene, D equal the frequency of the dominant homozygous genotype (BB), H equal the frequency of the heterozygous genotype (Bb), and R equal the frequency of the recessive genotype (bb). Then it follows that: $r + d$ equals 1.0, and $D + H + R$ also equals 1.0. In the example above: in the parent generation we have D equals 0.5, d equals 0.5, and r equals 0.5. In the F_1 generation, D and R both equal 0.0, and H equals 1.0, r and d remain unchanged. In the F_2 generation, D equals 0.25, H equals 0.5, and R equals 0.25, while r and d remain unchanged. If we mated our F_2 fish at random we should find that the next generation would come out in exactly the same proportions as the F_2. In fact we would find that in the absence of mutation, migration, or selection, this population is in equilibrium. This equilibrium condition was discovered by Hardy and Weinberg independently in 1908, and is generally known as the Hardy-Weinberg Law. This law gives the basic foundation from which we measure the effects of non-random mating, selection, migration, and mutation. The law states that $R = r^2$, $H = 2\,r\,d$, and $D = d^2$.

To illustrate how this law works let us take a hypothetical fish population consisting of 100,000 silver coloured fish. A fisheries biologist decides that there will be better fishing if the fish were all black instead of silver. Since he wants to keep the population number constant he fishes out 10,000 silver and replaces them with 10,000 black

ones. Then the law tells us that after one generation of random mating this population would consist of 1,000 black fish and 99,000 silver ones. The gene frequencies and genotype frequencies for the two generations would be: in the first generation: D and d both equal 0.9, R and r both equal 0.1. In the next generation d and r stay constant and the Hardy-Weinberg equilibrium is established at D equals 81,000, H equals 18,000, and R equals 1,000. Thus we have only 1,000 black fish instead of 10,000 which we put in, the other 18,000 of the original 20,000 black genes are now in the silver fish with the heterozygous genotypes (H). This point is important because in this position they are immune from any selective influence which act on black fish.

Suppose at this stage it is discovered that it is a mistake to have black fish in this lake, and it is decided to remove them by selective fishing. The formula that is used to show the effects of selection on such a population is:

$$r_1 \text{ equals } \frac{r^2_o (1 - s) + r_o d_o}{1 - s\, r^2_o}$$

where s equals the proportion selected out of the population, other symbols as before except subscript o refers to the original population, and subscript 1 refers to the first generation after selection. If we eliminate all of the blacks each generation so that s equals 1.0, then the formula simplifies to:

$$r_1 \text{ equals } \frac{r_o}{1 + r_o} \quad \text{or} \quad r_n \text{ equals } \frac{r_o}{1 + n\, r_o}$$

Using the first of these formulae, we find that if we fish out the 1,000 blacks, then r drops from 0.1 to 0.0909, and R drops from 1,000 blacks to 826 blacks. Thus the removal of all the black fish in the first generation would still allow the heterozygous silver s to produce 826 blacks in the next generation. If the population remains constant and the blacks are selectively fished out of each generation, we would expect to find the following numbers of blacks in each generation:—

Generation	0	1,000 blacks	Generation	5	444 blacks
"	1	826 "	"	6	391 "
"	2	694 "	"	7	346 "
"	3	591 "	"	8	308 "
"	4	510 "	"	9	277 "
			"	10	250 "

It may be seen from these figures that selection reduces the numbers fairly fast at first, but that selection is not very effective when the gene frequency falls to a low level. A slight modification of the formula tells us how many generations it would take to decrease the frequency from its present level to any selected level. For instance, to reduce R from 1,000 blacks to 10 blacks would take 90 generations, and long before it reached this level it would no longer be feasible to select out the black fish. From this example we see that once a recessive gene is introduced into the population it is impossible to remove it by selection.

When the large population is subdivided into several more or less discrete breeding populations, then the genetics of selection is changed, and the opportunity for a mutant to establish itself is also increased. Under these circumstances there is a slight modification of the Hardy-Weinberg law because mating is no longer completely random, but instead there is a slight amount of inbreeding. As an example, let us suppose

the 100,000 fish in the lake are divided into 10 separate breeding populations of 10,000 fish. Since very few adults would be needed each generation to produce 10,000 fish, then the effective breeding population is small and these populations will be subject to random drift, or Sewall Wright effect. The original population of 99,000 silvers and 1,000 blacks would be dispersed so that the variance of the 10 mean r values, one for each population, would be the same as the variance of r in the original large population. The variance is given by the formula:

r d / 2 N which in this case equals 0.1 × 0.9 / 200,000, or 0.0045. Since the mean r for the ten sub-populations is still 0.1, and the variance is 0.0045, then the distribution of r and the numbers of black fish in each of the sub-populations of 10,000 could be similar to the distribution given below:

Probable Distribution of Fish in Each of the Ten Sub Populations.

r	R	Number of blacks
.01	.0001	1
.02	.0004	4
.04	.0016	16
.05	.0025	25
.09	.0081	81
.1	.01	100
.14	.0196	196
.16	.0256	256
.18	.0324	324
.21	.0441	441
Total.....1.0		1,444
Mean..... .1		

From this it will be seen that while in a large population, $R = r^2$, the sum of a number of small populations in each of which $R - r_2$, gives a total population in which R is greater than r^2 by an amount equal to the variance of r. In other words, splitting a large population up into a number of small populations will lead to an increase in the homozygotes and a decrease in the heterozygotes. This is an inbreeding effect. Selection applied to such subpopulations to get rid of an undesirable recessive will be much more effective than it was in the large populations because more of the recessive genes will be exposed to selection. That is, more of the black genes will be in black fish instead of hiding in silver fish.

Much of the selection work in fish is not concerned with simple gene differences, but rather with quantitative differences such as egg size, fertility, body shape, flotation, etc. These quantitative characters are the result of the interaction of many genes with one another and with the environment. Selection presents a different problem in these cases since it is first necessary to remove the effects of the environment in order to find out what can be passed on by heredity to the next generation. The main principle involved is to assess the heritability by one of the many statistical methods, and then to utilize this knowledge to determine whether selection is possible, and also what speed of progress is possible with the various methods of selection. For instance, if heritability is 0.8 or more, then moderate selection by almost any method will be quickly effective, but if heritability equals 0.2 or less, then it is necessary to use a rigorous method of selection and also to eliminate the environmental effects.

In fisheries work, heritability is most easily calculated by the use of the parent offspring regression. As an example, suppose one is selecting for large egg size from a population which has an average egg size of two m.m. Then if we select fish which hatch from eggs of 4 m.m., our selection differential (S) is equal to 2. Then if these fish lay eggs which are 4 m.m. while the average for this next generation is also 2 m.m. then the response (R) is 2. From these two figures we find that heritability (h^2) is 1 (R/S), or that egg size in this case is a totally inherited character. If in the second generation the egg size had been only 3 m.m. then R would be 1 and h^2 would be 0.5. Of course a much more accurate method would be to work out the regression line of offspring on parent, where parental values are different a mid-parental value can be used. Then the slope of this regression line is equal to the heritability ($b = h^2$). Unfortunately we have no knowledge of the magnitude of the heritability values for the various characters in fish, and until we do we will not know how strong a selective force we need to apply in order to achieve the desired results.

Selectivity and Hybridization in Management of Fish Stocks

by

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Natural Selection and Artificial Selection

Broadly considered, selectivity may be related to management of fish stocks in two ways: (1) by natural environmental selection exerting its effects in conjunction with genetic variability over a very long time and (2) by artificial selection operating largely independent of the environment over a very short time.

Natural selection, plus an unknown number of successful mutations, in each species has resulted in a form or a pool of closely related variants unique in its adaptation to the environment. Within certain limits, the species can survive only in an environment in which it may complete its life cycle without the danger of elimination by lethal conditions at any one of what may be several critical developmental stages. Presumably, selective factors in the environment may eliminate individuals which can not easily adapt, while similar factors may favour the successful maintenance of those which can.

In the natural state, the forces of genetic variability and selection combine to give rise to new forms. This is a dynamic process, which appears to be dependent in part on the rate of mutation inherent in the species. In a relatively stable and protective environment, such as a hatchery, a new set of conditions is provided, where artificial selection makes possible a more rapid genetic shift than is likely to occur in the natural state. Intensive and continuous artificial selection may therefore result in observable changes in a relatively short period of time. Artificial selection may exert a strong influence also during commercial harvest of fishes. In some cases it is accidental, in others, by design; in extreme cases it may not be recognized until an obvious shift has occurred in yield or in character of the population.

Selection and Artificial Propagation

Where artificial propagation is used as an integral part of fisheries management programs, selective breeding is widely practised; it is also widely accepted as one of the major contributing factors in successful artificial maintenance of fish stocks. It would appear that most brood stocks presently in use have been adapted to hatchery practises in the following ways: (1) to obtain the most rapid rate of growth and best conversion of artificial foods into fish flesh; (2) to provide strains of fish most highly resistant to disease in the hatchery; (3) to provide the maximum number of eggs at the most convenient time for fish culture operations.

There is little question that fish culturists through selection have achieved a remarkable degree of uniformity in some strains of fish embodying, among other traits, the characteristics listed above. From the fish culturist's point of view, it would appear also that success in hatcheries has been high with the use of broodstocks if measured against results obtained from the culture of wild stocks. In this regard, there is ample evidence in the literature to show (Donaldson and Olson, 1956) that under identical conditions of feeding, density of population and so forth, selected domestic stocks are greatly superior to unselected wild stocks *in the hatchery environment.* It has been our experience in British Columbia that selected strains of rainbow trout can be raised in the hatchery for about one-sixth the cost of raising unselected wild strains of the same species.

The culture of fishes in hatcheries requires retention of stocks for considerable periods of time, varying from a few weeks to two or three years. Since cost of retaining fish is high, brood stocks and their progeny must be adapted to the regime of the hatchery, almost without regard for biological characteristics which might better suit them for survival in a natural environment. Behavioural patterns in particular may be altered by even a short exposure to an artificial environment. For instance Smith (1957) separated a wild stock of rainbow trout (*Salmo gairdneri*) into two groups at the eyed egg stage. One group was retained for hatching and rearing in a hatchery and the other was hatched and planted in a natural pond. After a year had elapsed, equal numbers of trout from each environment were transferred to a small lake. For the two years following their release into a common natural environment it could be shown most conclusively that the two groups of trout did not constitute a single aggregation, but rather tended to associate in groups according to whether their early life had been spent in a natural or in an artificial environment. Their survival rates were equal, but those reared in the hatchery had a significantly lower rate of growth in their second and third years.

A similar experiment was conducted by Vincent (1960) with eastern brook trout (*Salvelinus fontinalis*) using wild and domesticated stocks. Marked differences in behaviour and survival were clearly evident. Domesticated fingerlings in the hatchery were docile, while wild fingerlings exhibited alarm reactions when approached or handled. Survival of wild fish was up to 65 per cent greater than that of domestic fish after release from the protective hatchery environment.

The two foregoing examples illustrate clearly enough that effects of artificial selection are very rapid, and that early conditioning of fish by the hatchery environment may have important later effects on the fish in a natural environment. The fish culturist may justifiably claim that the use of brood stocks can increase the efficiency and subsequent output of hatcheries, resulting in greatly lowered cost per pound of fish produced. At the same time, however, unexpected results of selective breeding may lower the survival rate appreciably. If carried far enough, it is apparent that succeeding generations of fish could be affected adversely by characteristics introduced to the stock inadvertently, while selection was being carried out for quite another purpose.

Dr. R. B. Miller's work (1952) with cutthroat trout in Alberta streams demonstrated that hatchery reared trout could not compete with wild trout. A large propor tion of hatchery trout died of exhaustion when forced into a competitive role after

release from the hatchery. Miller suggested that the hatchery trout generally were unsuited to existence in a natural competitive environment and that lack of early natural selection in part at least was responsible for low survival.

Dymond (1956) reviewed the planting of whitefish and lake trout in the Great Lakes and concluded that where a spawning population already existed in the lakes, no effect of the planting of fry could be demonstrated, and that results of planting fingerlings were inconclusive but not encouraging. Miller (1953) investigated the alternate annual planting of whitefish eggs and fry in seven Alberta lakes over a 10-year period and showed that the plantings had no effect on year class strength in any of the lakes. Miller concluded that even the shortest exposure of a stock of fish to a hatchery environment has a definite but unknown effect which lessens chances of survival after release from the protective environment.

One fact thus is evident from published work to date, where comparisons are made between hatchery stocks and wild stocks utilizing a natural environment. In no case has it been shown that either selected hatchery stocks or hatchery reared, unselected wild stocks are superior to wild stocks reared completely in a natural situation. Rather, most work would appear to suggest that the reverse likely is true.

If the assumption can be accepted that even a short term exposure of a stock of fish to the artificial environment of a hatchery can lessen chance of survival in a natural environment, then it follows that selected brood stocks retained in an artificial environment for many generations are ill prepared indeed for survival in a natural competitive situation. The recent work by Vincent (1960) to which reference already has been made, strongly suggests that comparative survival studies should be made with a variety of stocks and under widely differing conditions. To this end, several strains of domestic rainbow trout presently used in British Columbia hatcheries have been planted together with wild native rainbow trout in several small British Columbia lakes. Initially, barren lakes have been chosen to eliminate the factors of predation and/or competition from other species. While it is premature to state which strains will survive best, it is apparent from early captures of marked fish that the domestic strains continue to grow at an extremely rapid rate in the wild. At the same time, however, domestic fish show unmistakably more rapid rate of sexual maturation than wild fish. Since mortality after spawning may be very high in rainbow trout (Hartman *et al*, 1961) early onset of sexual maturity in selected stocks may result in appreciable losses to the sport fishery. Wild rainbow trout, on the other hand (with the exception of precocious males) seldom spawn before three or four years of age, and thus are available to the fishery for considerably longer periods of time. Where no natural spawning facilities are present, and natural recruitment is not required to maintain the fishery, spawning at more advanced age is desirable, not only to reduce natural mortality, but also to preserve colour and palatability of immature trout so avidly sought by anglers.

While effects of artificial selection can result in rapid and large changes in behavioural patterns and can modify maturation and survival rates of fish, it should also be recognized that size of fish on release from the hatchery may be a critical factor in their subsequent survival in the natural environment. Studies carried out on Paul Lake in central British Columbia (Smith, 1955) showed that yearling rainbow trout (12-14 cm. in length and 18-20 gm in weight) resulted in a yield of more than 50 percent of the initial number stocked. A previous investigation (Larkin and Smith, 1954) had revealed

that natural recruitment of fry, together with substantial releases of fry and small fingerlings, could not provide sufficient catchable trout to sustain the sport fishery after introduction of a cyprinid competitor to the lake.

From the foregoing it follows that very careful evaluation is needed to provide fundamental information, both for selected and for unselected stocks regarding behaviour, growth, mortality, maturation and susceptability to capture, the last of which is in itself a selective factor (Larkin *et al*, 1950; Larkin and Smith, 1954; Haskell *et al*, 1952).

Environmental and genetic selective effects in themselves are difficult to separate, let alone compare. If complete data are not available for such effects for pure populations, then comparisons of populations of selected and unselected stocks have little precise meaning. From the paucity of literature concerning evaluation of success of planting progeny of selected stocks, it would appear that considerably greater importance should be attached to this phase of fish culture, in addition to the necessary, but perhaps overemphasized efforts to adapt fish to the protective environment of the hatchery.

Harvest Selectivity

A species' adaptation to its environment results in predictable patterns of behaviour and movement, and through knowledge of these man can effect a harvest from the population at a time when maximum yield can be obtained. During harvest, man may also direct much of his effort (either inadvertently or by calculation) towards selection of the most desirable individuals from a stock or he may choose to fish during seasons when the harvest is easily obtained and most saleable.

Intensive angling may result in selection of individuals with higher rates of growth (Larkin and Smith, 1954), either within an age group, or independent of age during any specified portion of the fishing season. Further, type of net (Ricker, 1942) or size of hook and skill of anglers (Hiyama and Kusaka, 1952) may produce similar effects of selection for size. Intensive commercial exploitation (Peterson, 1954) may be selective for size, age, sex or state of maturity. Many other examples could be described from information published to date. Suffice it to say, however, that it is highly probable that *all* fisheries, whether commercial or sport, exert *some* selective influence on the stocks being fished.

Where migratory stocks are involved in a seasonal fishery, as in the case of Pacific salmon and steelhead trout, the earlier tendency appears to have been to treat most fish migrating toward a particular river system as a "run", and to fish it as such. Ricker (1959) reviewed the published material on environmental and genetic influences on distinguishing characters of stocks of Pacific salmon and steelhead trout, and concluded that "most or all of the identified stocks of salmon differ genetically *to some extent*". Ricker suggested also that ". . . . . season of return to the river is strongly under genetic control . . . . . " (for salmon). This hypothesis also appears to be borne out (Smith, 1960) for steelhead trout. It would appear, therefore, that careful attention should be paid to selective action of fisheries where migrations extend over long periods of time and which may involve more or less separate stocks proceeding to different tributaries of a single river system.

Thompson (1951) suggested that, while a race or stock of salmon may exhibit a general characteristic, it nevertheless is composed of *individuals*, which have been selected and adapted to their reproductive environment over a very long time. Thompson

further suggested that an intensive fishery produces distortion in population structure, particularly with respect to the Karluk Lake run in Alaska, and that regulatory closures protected the early and late portions of the run, while the most productive central portion was depleted. The hypothesis was advanced by Thompson that the residual portions of depleted or overfished runs of salmon had an extremely high resistance to natural mortality, and cited as an example the explosive rebuilding of depleted runs of Fraser River sockeye, following the assistance provided in their upstream migration by fish ladders in the Fraser River canyon at Hell's Gate.

Royal (1953) suggested temperature as being the major, if not the exclusive controlling agent in timing of sockeye runs in the Fraser River watershed. For this reason the effects of regulatory selectivity were most important in preserving the mid-portion of runs which were closely adapted genetically in the timing of their migrations. Royal pointed out that vagaries of weather and high temperatures caused mortality in the eggs deposited by early fish and that low temperatures resulted in mortality of incubating eggs deposited by late fish. Thus the fishery for Fraser sockeye salmon should be regulated to take advantage of the higher reproductive potential of fish in the mid range of the total migration. Royal suggested that any change in the character of escapement caused by the fishery could be detrimental, although total escapement was adequate for the physical limitations of spawning areas.

The foregoing (and other) published accounts of the possible relation between exploitation and selection suggest that, other factors being equal, selectivity may severely limit the total productivity or yield of a stock of fish. Close attention therefore should be given the genetic character of each stock in formulating management plans.

Use of Hybrids in Fisheries Management

While the first known reference to hybrid trout was made in 1879 (Martin, 1960), it would appear that to date hybrid populations have not contributed significantly to any major fishery. Nevertheless, research in hybridization appears to have accelerated, particularly since 1950. Several agencies on this continent (among others, the Research Branch, Ontario Department of Lands and Forests and the Pennsylvania Fish Commission) have well developed programs for investigating genetics of fish stocks. More particularly, considerable effort has been directed to the hybridization of lake trout (*Salvelinus namaycush*) and brook trout (*Salvelinus fontinalis*). Other crosses of trout (brook x brown, brown x rainbow, rainbow x "splake", etc.) also have been achieved.

Although wide use has not yet been made of hybrid populations to support substantial fisheries, hybridization studies would appear to offer geneticists and fisheries taxonomists a fertile field for investigation of genetical problems in fish populations. In addition to the knowledge to be gained from fundamental research in hybridization, application of research findings could be of great value to fishery managers.

The indifferent success obtained with many crosses of closely related species leaves such work open to further exploration. It would appear, however, that with some exceptions, breeding populations of inter-species hybrids generally do not occur naturally, or if they do occur, the characteristics of one species may all but mask the occurrence of characters transmitted to offspring from another species and hybrid populations may exist unrecognized (Alm, 1955).

In the field of agriculture accounts are numerous of hybrid rust-resistant wheat and productivity of hybrid corn. These successful hybrids can be considered as inter-strain or interracial crosses, and in fisheries, would seem to offer similar chances of success which have been so startling in the production of cereal foods.

(Donaldson, *et al*, 1956) performed a simple cross of selected brood stock cutthroat with cutthroat from a wild population. The resulting progeny from a two-way cross, together with progeny from each set of parents, were marked and planted in a small Washington lake. Both sets of hybrid progeny (called "interracial" by Donaldson *et al*) occurred in anglers' catches up to two years later in numerical strength from three to six times greater than the progeny from either set of parents.

The interracial crosses resulting in apparent hybrid vigour and recorded increase in survival of cutthroat trout bear repeating with other species such as rainbow, brook, brown and lake trout which are so important in sport fish management. Much research will be required before the transfer of desirable characteristics can be predicted with certainty, but results could be very important.

Wild stocks of trout of several species may be crossed readily with almost any number of domestic brood stocks, or domestic stocks heavily line-bred for many generations could be crossed with each other. One of the chief drawbacks to hybridization studies is that of the time required to raise parent stock to maturity. With modern air transport, however, first crosses could be made easily by exchanges of sperm and eggs of the various stocks between co-operating fisheries agencies.

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The Effects of Underwater Explosions on Yellow Perch (*Perca flavescens*)

by

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Abstract

The lethal effect on fish of various explosive charges detonated underwater at 5 to 10 feet below the surface was assessed. The numbers of free fish that had been killed and which had floated to the surface were not a reliable measure of charge lethality because of variations in the abundance and distribution of free fish. Captive yellow perch held in cages at 10 feet from the surface and at the bottom at direct distances from 25 to 207 feet provided a more reliable assessment of charge lethality. Black powder when detonated with an electric squib produced fatal injuries in few or no perch, but when detonated with a nitrone primer produced fatal injuries in perch at distances up to 100 feet. The destructive effect in this latter charge was due primarily, if not solely, to the nitrone primer charge. A nitrone primer charge produced fatal injuries in nearly all fish to 50 feet and injured some to 200 feet. A twenty pound nitrone charge produced fatal injuries in nearly all perch to 200 feet. Nearly all injuries involved the swim bladder or associated tissues. Laboratory examination was used to determine fatalities.

Introduction

Explosive charges regardless of size or composition are generally considered damaging to fish. Therefore, when an oil and gas exploration company requested permission to test explosives for seismic exploration in Lake Erie the Ontario Department of Lands and Forests granted the request on condition that no damage to fish result from the tests. The Ontario Department stipulated that charges to be tested for seismic value should at the same time be tested for their possible effects on fish. Various types and sizes of explosive charges were tested in Lake Erie near Wheatley, Ontario during August 8, 10 and 12, 1958.

There are published reports on the effects of underwater explosions on fish (see Aplin, 1947; Fitch and Young, 1948; Hubbs and Rechnitzer, 1952, and others), but these are almost exclusively concerned with marine fish; there are only casual observations published on the effects on freshwater fish. Hubbs and Rechnitzer (1952) established the value of using caged fish to assess the effect of an explosive charge; this approach has been extended here. In the present experiment cages were also used, but in a different manner. The cages as used here were spread out in line away from the charge, rather than being relatively close together as in the experiments of Hubbs and Rechnitzer (1952). By using the cages in this way both the lethal effect of a particular charge and the distance it was lethal could be assessed.

The value of the explosive charges for seismic purposes was not the concern of the writer and will not be considered here.

Acknowledgments

Canadian Kewanee Limited made up and detonated the explosive charges in accordance with the conditions of the tests. Dr. J. K. Reynolds, District Forester, Department of Lands and Forests, Aylmer, Ontario, was particularly helpful in making arrangements with the company consistent with the design of the experiment. Staff of the Lake Erie unit of the Research Branch who participated in the project were: B. Bidgood, L. Drummond, D. Frederisy, J. Kippax, J. Murphy, R. Pilfrey, and G. Yarrow. The writer is indebted to Mr. K. H. Loftus, Dr. J. S. Tait and the Editorial Board of the Research Branch for reading the manuscript and for their many helpful suggestions.

Materials and Methods

Cages

Ten wire mesh ($\frac{3}{4}$" square) cylindrical cages, 18 inches in diameter and 36 inches long were used to hold live yellow perch at various distances from the explosive charge. These cages were attached, two to each of five buoyed anchor lines; one at the bottom and one at ten feet from the surface. The water depth on Aug. 8 was 58 feet, on Aug. 10 and 12 it was 42 feet. Another anchored buoy served to mark the location of the explosive charge. The five buoys supporting cages were positioned in line at 25, 50, 100, 150 and 200 feet from the "charge" buoy. The locations of the cages in relation to the charge are shown in Figure 1.

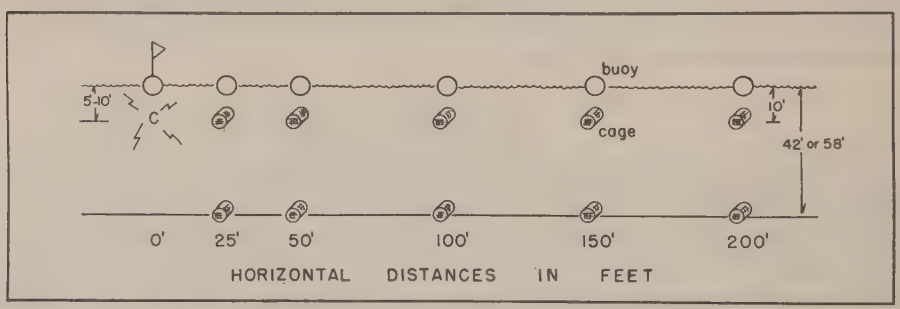

FIGURE 1.—*Diagram showing the distribution of the cages relative to the explosive charge (C). The charge was suspended from the flagged buoy at either five or ten feet from the surface. All buoys were attached to a light line at the designated distance from the charge buoy. The flagged charge buoy was not anchored, but all other buoys were anchored (anchors not indicated above). The cages were attached to the anchor lines; one at ten feet from the surface and one at the bottom (58 ft. first day; 42 ft. second and third days).*

Explosives

The names and technical designations of the explosives are those used by Canadian Industries Limited. These explosives were:

Nitrone,
Nitrone primer, or starter (S1) one pound sealed in a can,
Black powder (BTC-23-F-65),
Squib cap (No. 89, electric).

The black powder was in kernel form, and to make up charges the appropriate weight of powder was poured into a waterproof container, the detonator was inserted and a length of electric cord was attached. The electric cord allowed the charge to be fired from the lake surface at the proper time.

There were 18 charges detonated during the three days of tests; five charges on August 8 (A1 to A5); eight on August 10 (B1 to B8), and five on August 12 (C1 to C5). There were 14 black powder charges; four were detonated with S1 nitrone primers and ten with electric squib detonators. Three charges consisted of S1 nitrone primers alone; two each consisted of one S1 and one of two S1 nitrone primers. A single nitrone charge consisting of twenty pounds of nitrone was detonated with an S1 nitrone primer.

At the beginning of the tests, charges of black powder were placed in plastic bags, but later (August 10, charges B6, B7 and B8 and all charges on August 12) they were placed in welded steel containers. The reason for the use of the steel containers was to increase the initial shock wave (see Hubbs and Rechnitzer, 1952, comments) in order to produce enough energy for a good seismic record. During the first day black powder charges were detonated with S1 nitrone primers, but later electric squib detonators were used (see Table I).

TABLE I.

Number of each species of fish found dead on the lake surface after each charge was detonated

Charges are arranged in chronological order. The charge types are designated as BP for black powder or N for nitrone. The detonators are designated as S1 for a nitrone primer and as E for an electric squib detonator.

No.	Charge			Species of Fish			
	Type	lbs.	Detonator	Yellow Perch	Lake Em. Shiner	American Smelt	White Bass
A1	BP	12.5	S1	—	—	—	—
A2	BP	50	S1	—	1	2	—
A3	BP	50	S1	—	—	—	—
A4	BP	55	S1	—	6	—	—
A5	N	20	S1	85	1	5	—
B1	—	—	S1	3	17	3	—
B2	—	—	S1	5	26	—	1
B3	BP	50	E	—	—	—	—
B4	BP	100	E	—	—	—	—
B5	—	—	2S1	3	21	—	1
B6	BP	16	E	—	—	—	—
B7	BP	30	E	—	—	—	—
B8	BP	24 (to 25?)	E	—	—	—	—
C1	BP	30	E	NIL ALL CHARGES			
C2	BP	40	E				
C3	BP	40	E				
C4	BP	50	E				
C5	BP	25	E				

Procedure

Live yellow perch obtained from local pound nets were transported in tanks supplied with fresh water to the test site just prior to the experiments. Ten of these fish were placed in each cage just before charge detonation. Then (in several cases) the area around the charge was echo-sounded (Bendix DR-9 echo-sounder) to give some indication of the presence and distribution of free fish. After the explosion all dead fish on the surface were collected and the caged fish (except after charges A1 and A2, see Table I) were removed. All fish were placed in ice in separate containers pending detailed laboratory examination.

The first two charges (A1 and A2) were suspended at ten feet below the surface; the remainder at five feet. Charge A2, which was supposed to be suspended at ten feet, may have dropped to the bottom since this charge alone brought muddy water to the surface.

During August 8, 1958, firing was conducted 14.5 miles, 144° from Wheatley, Ontario; on August 10th at 5.5 miles, 70°, and on August 12th at 5 miles, 72° from Wheatley. The water depth (and the depth at which bottom cages rested) was 58 feet on August 8 and 42 feet on August 10 and 12. Although the firing location was different on different days, the buoys, cages and charge buoy once positioned for a given day's firing remained in the same location during that day. When caged fish were not being tested, charges were detonated at least one mile away from the cages.

Criteria used in determining fatal injuries

The criteria used here were similar to those employed by Hubbs and Rechnitzer (1952). External damage was never severe, but internal damage of the following nature was considered fatal:

1) free blood in the coelom,
2) ruptured swim bladder,
3) free blood in the swim bladder,
4) ruptured left posterior cardinal vein,
5) ruptured kidney,
6) free blood in the pericardium, or
7) extensive haemorrhage in the brain.

Observations and Results

Bathythermograph casts during the tests showed that the epilimnion was 45 feet deep in the offshore area used on the first day, but was only 20 to 25 feet deep in the inshore area on the other days. Echo-sound traces at the offshore and inshore locations indicated that the abundance and vertical distribution of the fish was influenced by the prevailing thermal stratification, and possibly the relative distance from shore. During the first day the echo-sounder indicated that there were no concentrations of fish in the epilimnion, but rather a scattering of fish throughout. Late in the day there were indications of concentrations of fish in the upper hypolimnion, however. During the second and third days, when the epilimnion was shallower, and the tests were conducted closer to shore, greater numbers of fish were indicated in the epilimnion. There were consistent patterns of fish indicated on the echo-sounder throughout each day's tests suggesting that the series of explosions had no major effect on the distribution of fish in the immediate vicinity of the explosions.

Dead fish on the lake surface

Table I shows the collections of dead fish by numbers of each species collected from the lake surface after each explosion. These collections were complete with the possible exception of a few emerald shiners (*Notropis atherinoides*) and white bass (*Morone chrysops*) that were small enough to slip through the meshes of the dipnets.

There were no fish brought to the lake surface by black powder charges of up to 100 pounds when they were detonated with electric squibs. However, three and six

fish were killed by two of four black powder charges of 50 and 55 pounds when a nitrone primer (S1) was used to detonate the charges. Larger numbers of fish were brought to the lake surface on the second day by charges consisting of nitrone primers alone. Comparable numbers of yellow perch and lake emerald shiners were brought to the surface by these latter charges, plus a few smelt and white bass. The largest number of fish were killed by charge A5 which consisted of 20 pounds of nitrone detonated by a nitrone primer.

Laboratory examination of fish collected at the lake surface

All fish collected at the lake surface were examined in the laboratory with the exception of the nine fish from charges A2 and A4; these were inadvertently discarded. There were 180 fish collected at the lake surface and all had received injuries that were considered fatal.

All 96 yellow perch collected at the lake surface had major ruptures of the swim bladder, most showed severe haemorrhaging of the kidney (90%) and segmental blood vessels (92%), 66% had an accumulation of blood in the coelom resulting from haemorrhage of the kidney or rupture of the left posterior cardinal vein, 54% had free blood within the pericardium, and 35% showed haemorrhaging around the vent or eyes.

The coelomic organs of the 65 emerald shiners collected at the lake surface deteriorated rather quickly in spite of being placed in ice. Those that were examined at the time of collection showed severe and general haemorrhage of the coelomic organs and lateral body wall. Laboratory examination of the best preserved specimens showed extensive haemorrhage of the kidney, rupture of the posterior cardinal vein and large amounts of blood in the coelom.

The eight smelt collected showed the same injuries as did the perch with the exception that brain and eye haemorrhage was more prevalent.

Attempts at bottom trawling to assess the numbers of injured fish that might have sunk to the bottom produced six perch. Four of these had severe air bladder or heart injuries, and two had no apparent injuries. It was considered that the trawl was not operating properly and therefore extensive trawling was not attempted.

Caged fish results

A record was kept of the numbers of perch that were apparently dead when the cages were brought to the surface, but laboratory examination was used to determine whether or not the fish had received fatal injuries. Table II shows the fatalities in caged perch after various charges had been detonated. It should be pointed out that the distances given in this table are not the direct distances between the charge and the cages, but are horizontal distances. The surface cages were almost at the same depth as the charges and the direct distances are at the most 0.5 feet further than the horizontal distances. The direct distances of the bottom cages from the charges are given below:

Charges Horizontal distance	25 ft.	50 ft.	100 ft.	150 ft.	200 ft.
A1 — A5 Direct distance	59	73	113	159	207
B1 — C4 Direct distance	45	62	107	154	203

In general, few or no fatal injuries were observed in perch that had been subjected to explosions of up to 100 pounds of black powder and which had been detonated

with electric squibs. This was true whether the charge had been confined in a plastic bag or welded steel container. The two charges A3 and B2 (see Table II) produced comparable results in fatalities (41 and 44) to caged perch even though the first was fifty pounds of black powder detonated by a nitrone primer and the second was a nitrone primer alone. Possibly, however, the caged fish results shown for charge A3 may be suspect and not comparable to results from the other charges since most of these fish had been subject to the two previous explosions. There were fatalities in the cages as far away as 200 feet, but the majority were killed at 100 feet and less. By far the greatest number of fatalities were caused by the 20 pound nitrone charge, A5, when nearly all caged perch received fatal injuries even to the furthest cage at 200 feet.

TABLE II.

The numbers of Perch sustaining fatal injuries in cages at various distances from the explosions.

Surface and bottom cages are indicated thus; surface/bottom.
Symbols are the same as used in Table I.

	Charge			Horizontal distance from charge				
No.	Description			25 ft.	50 ft.	100 ft.	150 ft.	200 ft.
A1	BP	12.5	S1	10/4	remainder not removed for examination			
A2	BP	50	S1	/8	remainder not removed for examination			
A3	BP	50	S1	10/6	8/2	10/5	0/0	1/0
A5	N	20	S1	10/10	10/10	10/10	10/?	9/6
B1			S1	2/7	remainder not removed—charge off position 150′			
B2			S1	10/10	9/8	0/3	1/1	2/?
B3	BP	50	E	1/0	2/0	0/0	0/0	0/?
‡B4	BP	100	E	2/0	0/0	0/0	0/0	0/?
C1	BP	30	E	1/1	0/1	0/0	0/0	0/?
C4	BP	50	E	0/0	0/0	0/0	0/0	0/?

?—no caged fish exposed

‡—5 fish only exposed in cages at 25 and 50 feet, therefore 2 recorded in surface cage at 25 feet represents 1 in 5 receiving fatal injuries

Table III below summarizes the fatalities in caged perch according to charge type. Black powder when detonated with an electric squib produced practically no fatalities, but when detonated with a nitrone primer nearly half the perch were fatalities. As suggested earlier this was comparable with the results from a nitrone primer alone. Nitrone was the most destructive and killed nearly all perch.

TABLE III.

The number and percent of fatalities in caged Perch resulting from the exploding of different charge types.

These data are derived from Table II. "No. Perch" refers to the number of Perch exposed to the type of charge in question.

Charge type	No. Perch	Mortalities	
		No.	%
Black powder-electric squib	360	8	2.2
Black powder-S1 det.	100	42	42.0
S1 detonator only	90	46	51.1
Nitrone-S1 detonator	90	85	94.4

Injuries received by caged perch

In general, caged perch were either not injured, or they were severely and fatally injured by the explosive charge. There were 640 caged perch exposed to the explosions and 179 or 27.9% received fatal injuries. These injuries included haemorrhage of the segmental vessels (83.8%), haemorrhage in the kidney tissue or left posterior cardinal vein passing through the kidney (74.3%), swim bladder rupture (67%), heart rupture (36.6%) and external haemorrhage (37.9%). These percentages are based on the number of fish considered as having received fatal injuries, not on all the perch exposed. There was a difference in the prevalence of the type of injuries incurred by the perch in the surface cages when they are compared with those incurred by perch in the bottom cages. Perch in the surface cages sustained more swim bladder injuries and fewer kidney and segmental vessel injuries as is pointed out in the following table:

	Swim bladder	Kidney	Segmental vessels
Surface cages	90.6%	59.8%	79.4%
Bottom cages	31.9%	95.8%	90.3%

Discussion

The present results show that black powder, when detonated with an electric squib, was relatively innocuous to yellow perch. Black powder was not harmful to various species of marine fish either according to Hubbs and Rechnitzer (1952), Fry and Cox (1953) and Baldwin (1954).

The nitrone charges, on the other hand, were decidedly harmful to yellow perch and other species of fish. Even a one pound S1 charge (see Charge B2, Table II, Figure 2) killed some perch at distances up to 200 feet. This suggests that nitrone is more destructive to fish than is dynamite as judged by the figures for this latter explosive presented by Hubbs and Rechnitzer (1952). Their figures indicate that five pounds of dynamite could kill marine fish at distances up to 60 feet from the charge.

The captive perch held in cages at various distances from the explosion provided the best measure of charge lethality. The kill of free fish which floated to the lake surface was not reliable for assessing the harmful effects of an explosion. This is true because the distribution and abundance of free fish in an area determine, to a large extent, the numbers that may be affected by an explosion. For instance, charges A1 to A4 exploded on August 8 were similar and produced a small free kill of from 0 to 6 fish. This was in an offshore area where the epilimnion was deep and where echo-sounding indicated few fish. On the second day charges B1, B2 and B5, which were smaller and presumably not as destructive as those on the first day, produced a much larger free kill. On the second day this was in an inshore area with a shallow epilimnion and where echo-sounding indicated greater concentrations of fish. The free kill is a poor measure of charge lethality for another reason; an unknown number of fish may suffer fatal injuries and fall to the bottom. This was not adequately assessed here, but four perch that had received fatal injuries were collected at the bottom.

Captive perch were held in bottom and surface cages to see whether this might affect their survival, but the depth at which the fish were held did not appear to have any bearing on whether or not fatal injuries were received. The direct distance between the

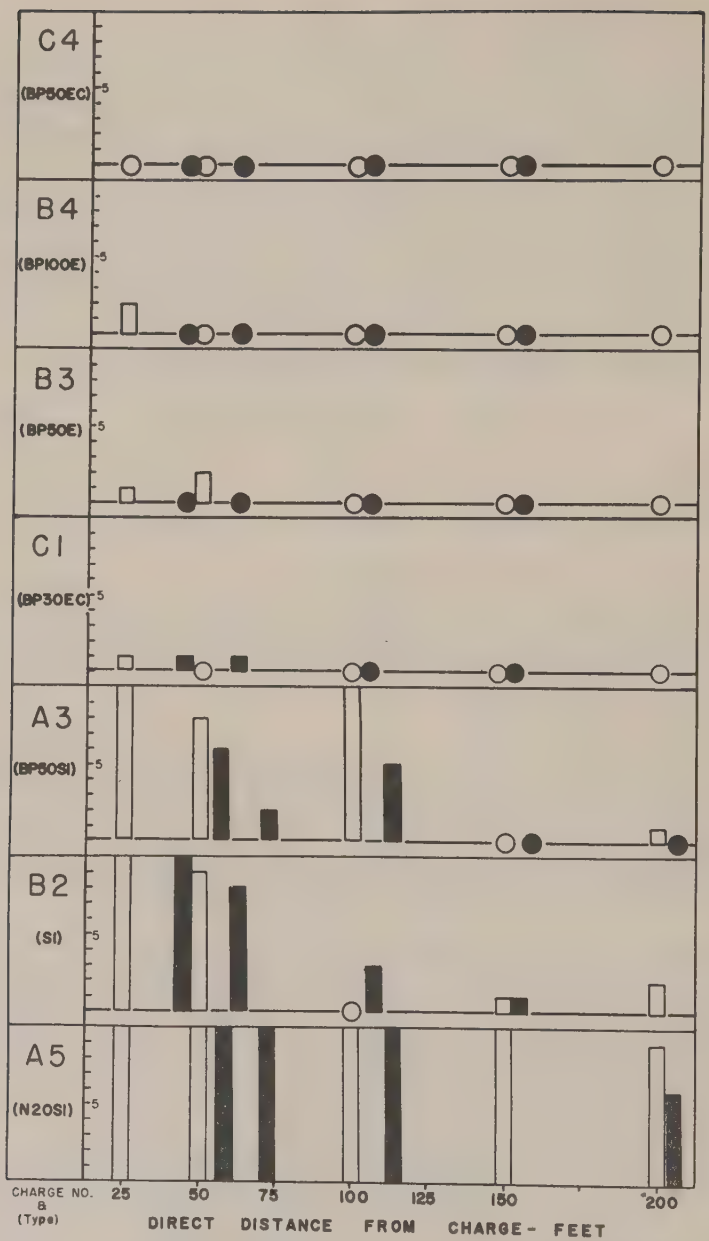

FIGURE 2.—*The number of perch with fatal injuries in cages containing ten perch at various distances from explosive charges. Open histograms indicate fatalities in surface cages and closed histograms the number of fatal injuries in bottom cages. The small circles (open-surface; closed-bottom) indicate cages in which there were no fatal injuries. The distances indicated are direct distances between the charge and the cage. These results are arranged, from top to bottom, in order of increased number of total fatal injuries. The charges were numbered consecutively during each day with Day 1 being designated A, Day 2, B, and Day 3, C. The charge type designations are: BP-black powder; the number indicates the weight of the charge in pounds; E-electric squib detonator; C-charge confined in a steel container; S1-1 lb. nitrone starter (detonator), and N-nitrone.*

explosion and the fish is more important. This is best illustrated in Figure 2. The prevalence of swim bladder injuries in perch held near the surface, and the prevalence of kidney (and associated) injuries in perch held at the bottom does not alter this. Apparently the destructive power is the same at the two depths used here, when the direct distance is equal, but the prevalence of either swim bladder or kidney damage differs at the two depths.

Initial tests of black powder charges detonated with nitrone primers proved such charges to be most destructive to fish. Subsequent firings of nitrone primers alone (compare A3 and B2, Figure 2) indicated that in the black powder-nitrone primer charge the latter component was the lethal agent.

The circumstances of these tests made it necessary to remove the caged fish immediately after each explosion. It would have been desirable to hold these fish for observation and then record actual deaths and survivors rather than assess the mortalities from injuries. In defense of the procedure adopted it can be said that the injuries were generally either severe or non-existent. Thus even though judgment was required in all cases, doubtful fatalities were at a minimum and the reliability of the results was not affected.

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Book Review

Pêches continentales—biologie et aménagement. By R. Vibert, Ingénieur principal des Eaux et Forêts, Directeur de la Station d'Hydrobiologie appliquée de Biarritz, and K. F. Lagler, Department of Fisheries, University of Michigan, 720 pp., 164 figs. Dunod, 92 rue Bonaparte, Paris, 1961.—The 21 Chapters of this compendium are as follows:

1. The problems
2. Ecology and ecosystems
3. Concepts and principles concerning energy in ecosystems
4. Heredity
5. Environment
6. Social organization
7. Evolution of ecosystems—ecological succession
8. Mathematical theory of fisheries
9. Management of the environment
10. Management of preferred species
11. Management of fishing
12. Public relations
13. Management of artificial waters
14. Management of natural waters
15. Management of unusual waters
16. Statistical analyses
17. Fish marking and tagging
18. The study of age and growth of fishes
19. Feeding habits and food rations
20. Population inventories and catch statistics
21. Ecological assessment of fisheries

Under each of these chapters the Table of Contents lists up to two pages or so of subheadings, classified on a decimal system to six significant figures. It is safe to say that the authors have omitted no important idea or procedure in the recent literature of freshwater ecology and fishery biology. To the above must be added four appendices, including two statistical tables, the scientific names of fishes and vernacular names in French and English, and conversion tables from metric to English units. There is a good 14-page index.

It is evident that the French encyclopedic tradition has triumphed over American eclecticism in producing this very useful reference book. As with any encyclopedia, each reader can amuse himself by deciding what *he* would have given more emphasis, or less, but I have no complaints that could be justified on general or theoretical grounds. Illustrative material is drawn from a wide area. Pictorial illustrations are numerous and well reproduced; a few are in colour. Among much else, they show trout stream improvements in Michigan, bass-bluegill culture in Alabama, *Tilapia* ponds in the Congo,

rice-field carp culture in Japan, milkfish and shrimp rearing in the brackish tambaks of Java, erosion in Madagascar, terraced hillsides in Morocco, "standard" fishways at Bonneville, Denil fishways at Oloron, the Lowestoft pin-ball machine for demonstrating desirable rates of fishing, and one of those cane-pole anglers of the Seine embankments who so appropriately illustrate "sedentary fishing by amateurs"—to mistranslate the caption slightly.

With so much photographic space available, the publisher should have insisted that good likenesses of both authors be included and identified, in some supporting role if necessary. Actually Dr. Lagler makes a recognizable though anonymous appearance on page 625; but it is difficult to know whether or not the individual on page 442, engaged in planting a "Vibert" box of trout eggs, would reveal M. Vibert's customary cheerful smile if he were to turn his head toward us.

In Canada, of course, this book will have its largest audience in the French-language region. But it is also fairly easy reading for English-speaking people with no more than the usual high school French. For this we must primarily thank our versatile ancestors, who maintained a general bilingualism for as long as two centuries but who eventually became so mixed up that in Britain French and English were amalgamated into one language. Just as important for our understanding, however, is Vibert's direct and logical style, which justifies the publisher's claim that the text is written "dans une langue accessible au plus grand nombre possible des lecteurs".—*W. E. Ricker, Fisheries Research Board of Canada, Nanaimo, B.C.*